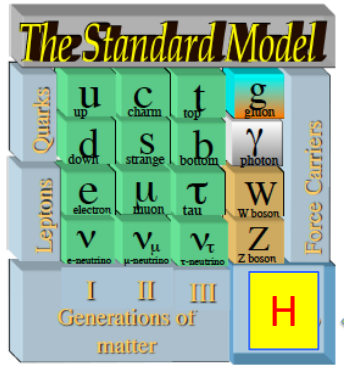
# Recent ILC R&D status

*Shin MICHIZONO*
*KEK/Linear Collider Collaboration (LCC)*

- *250GeV ILC*
- *Nano-beam R&D*
- *Cost reduction SRF R&Ds*
  - *Directly sliced Nb material*
  - *N-infusion*
- *SRF accelerators*
- *Fukuoka Statement/ILC symposium*

# Important Energies in ILC

125 GeV Higgs discovery reinforcing the ILC importance




Integrated Luminosity ($ab^{-1}$)

2

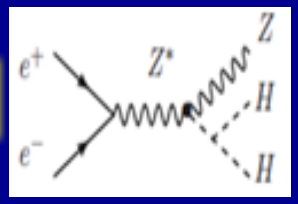
1

**Physics confident:**

→ **Higgs** and **Top Quark**

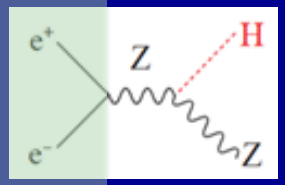
- Learn "everything" about H (125)
- Probe dynamics of EWSB

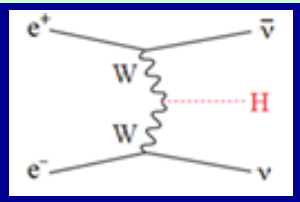
HHZ

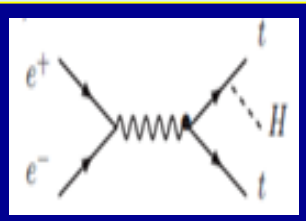



**New Physics beyond SM:**

- Direct or indirect **DM searches**
- Evidence for BSM physics
- Hints of a new mass scale




HZ

$\bar{\nu}\nu H$

$t\bar{t}$

$t\bar{t}H$

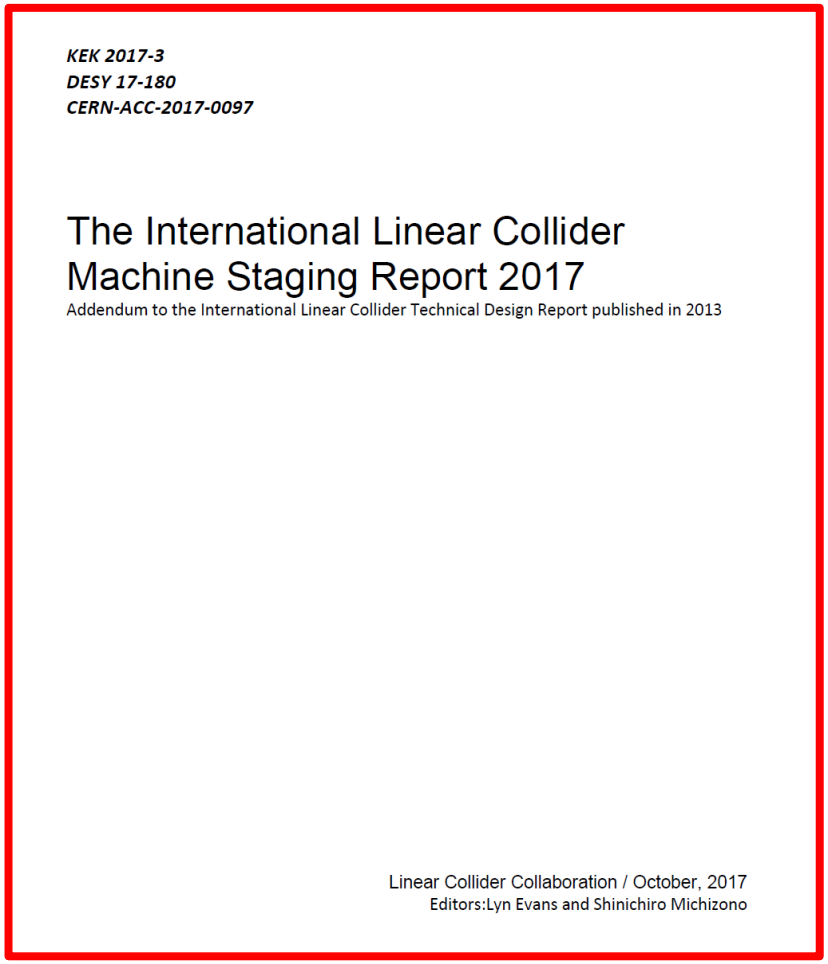
**LEP** reached→

200 300 400 500 600 $E_{cm}$ (GeV)

# Machine/Physics report (October 2017)

https://arxiv.org/abs/1711.00568

https://arxiv.org/abs/1710.07621



*KEK 2017-3*
*DESY 17-180*
*CERN-ACC-2017-0097*

The International Linear Collider
Machine Staging Report 2017

Addendum to the International Linear Collider Technical Design Report published in 2013

Linear Collider Collaboration / October, 2017
Editors:Lyn Evans and Shinichiro Michizono



DESY-17-155
KEK Preprint 2017-31
LAL 17-059
SLAC–PUB–17161
October 2017

Physics Case for the 250 GeV Stage
of the International Linear Collider

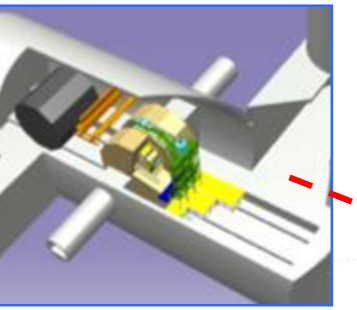
LCC Physics Working Group

Keisuke Fujii[1], Christophe Grojean[2,3], Michael E. Peskin[4] (Conveners); Tim Barklow[4], Yuanning Gao[5], Shinya Kanemura[6], Hyungdo Kim[7], Jenny List[2], Mihoko Nojiri[1,8], Maxim Perelstein[9], Roman Pöschl[10], Jürgen Reuter[2], Frank Simon[11], Tomohiko Tanabe[12], James D. Wells[13], Jaehoon Yu[14]; Mikael Berggren[2], Moritz Habermehl[2], Sunghoon Jung[7], Robert Karl[2], Tomohisa Ogawa[1], Junping Tian[12]; James Brau[15], Hitoshi Murayama[8,16,17] (ex officio)

ABSTRACT

The International Linear Collider is now proposed with a staged machine design, with the first stage at 250 GeV with a luminosity goal of 2 $ab^{-1}$. In this paper, we review the physics expectations for this machine. These include precision measurements of Higgs boson couplings, searches for exotic Higgs decays, other searches for particles that decay with zero or small visible energy, and measurements of $e^+e^-$ annihilation to $W^+W^-$ and 2-fermion states with improved sensitivity. A summary table gives projections for the achievable levels of precision based on the latest full simulation studies.

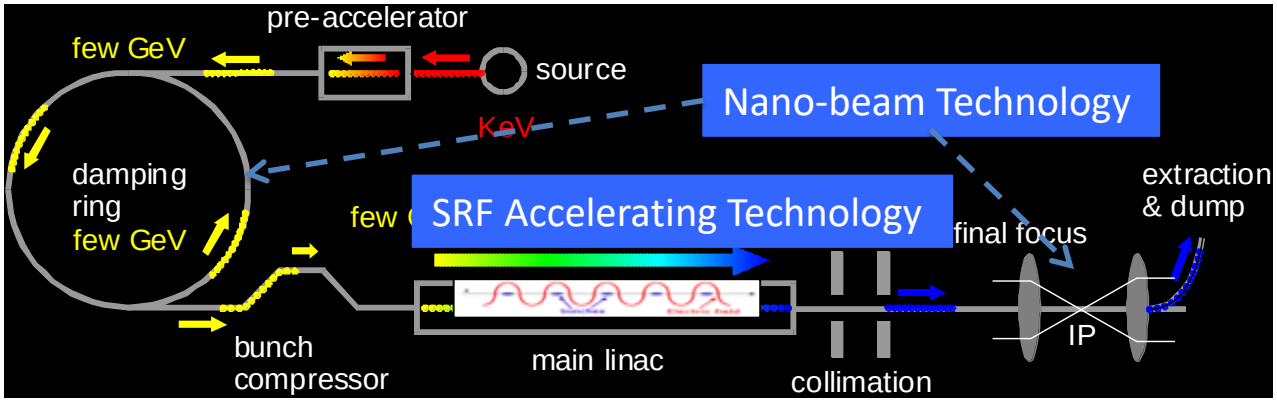
# ILC250 Acc. Design Overview



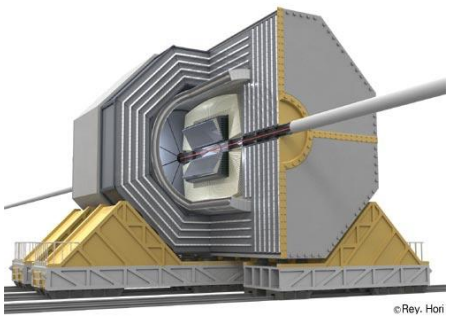
Physics Detectors



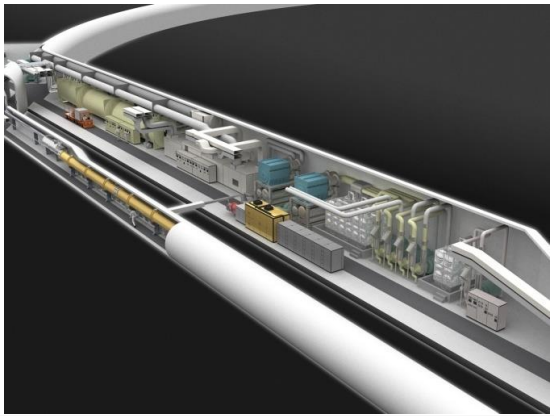

## Key Technologies

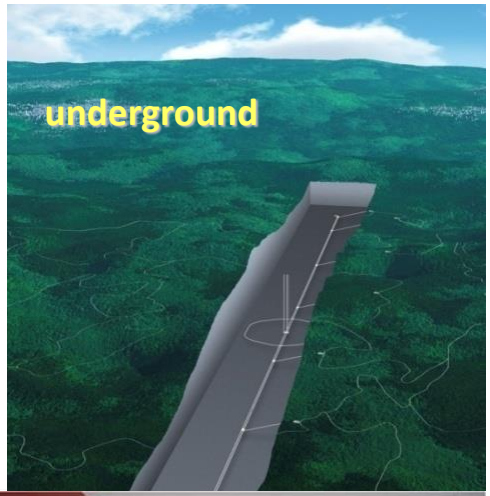



| Item | Parameters |
|---|---|
| C.M. Energy | 250 GeV |
| Length | 20km |
| Luminosity | 1.35 x$10^{34}$ $cm^{-2}s^{-1}$ |
| Repetition | 5 Hz |
| Beam Pulse Period | 0.73 ms |
| Beam Current | 5.8 mA (in pulse) |
| Beam size (y) at FF | **7.7** nm@250GeV |
| SRF Cavity G.<br>$Q_0$ | **31.5** MV/m<br>(**35** MV/m)<br>$Q_0$ = 1x$10^{10}$ |

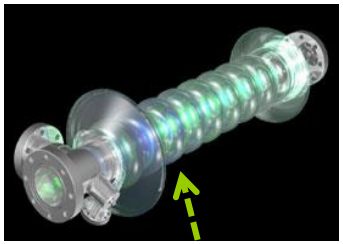


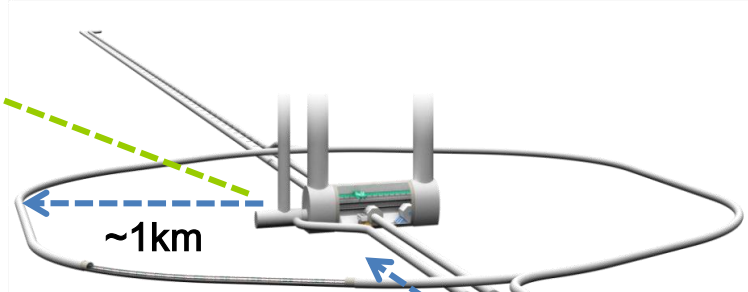

Detector

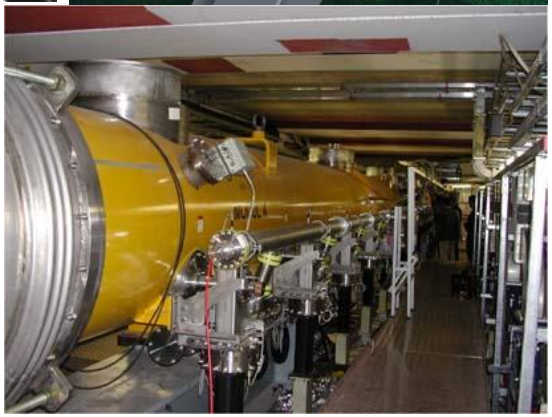


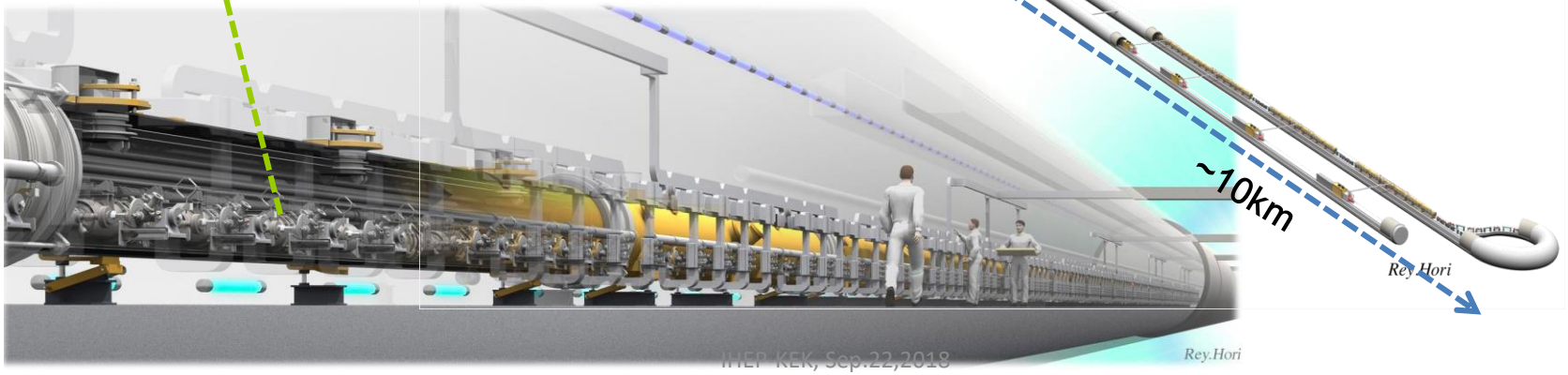



Superconducting cavity

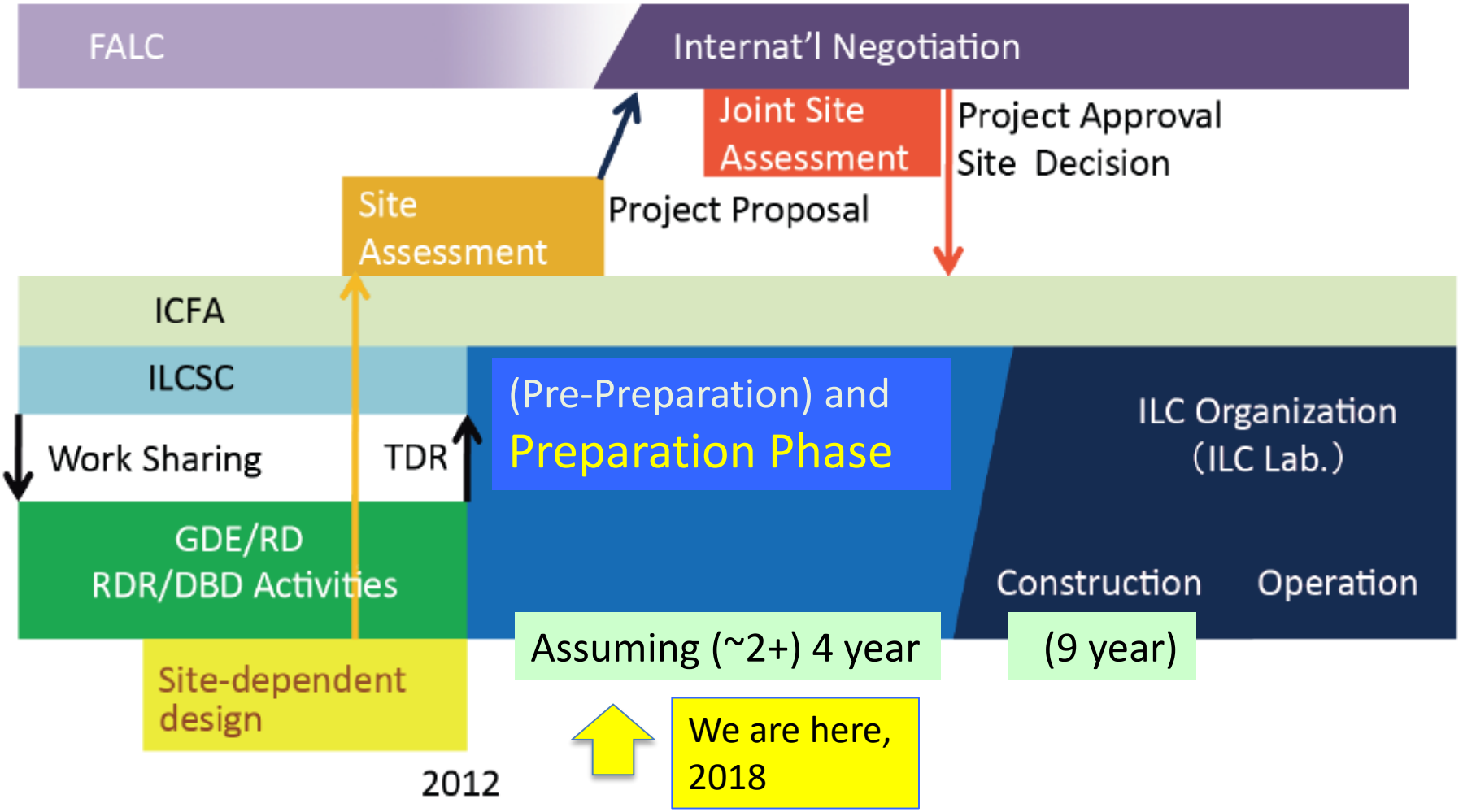






# ILC Time Line: Progress and Prospect



# ILC Site Candidate Location in Japan: Kitakami

- Preferred site selected by JHEP community,
- Endorsed by LCC, in 2013


High-way

Express-Rail

Sendai

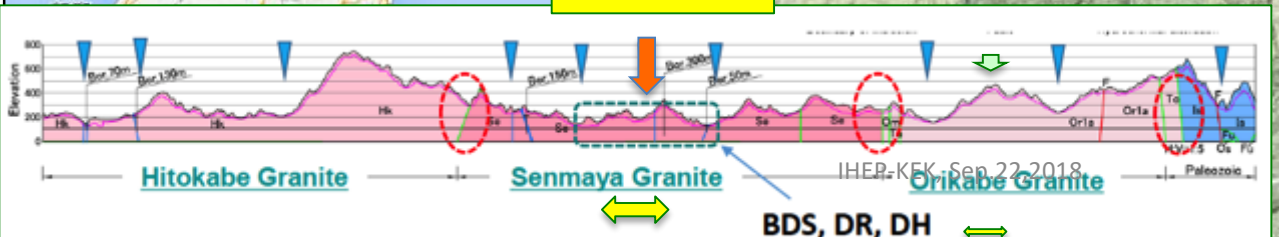
Oshu

Ichinoseki

Ofunato

Kesen-numa

IP Region



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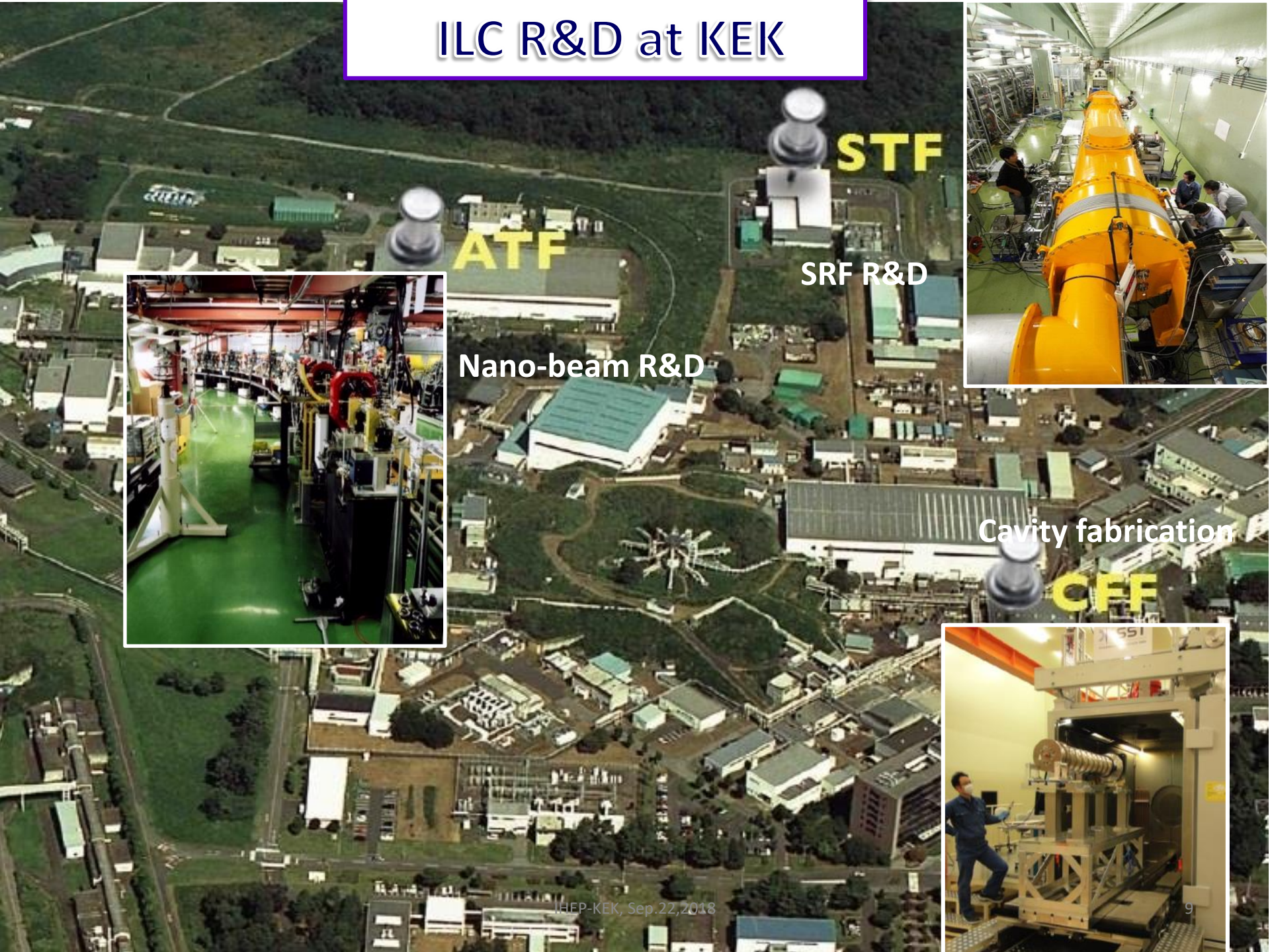
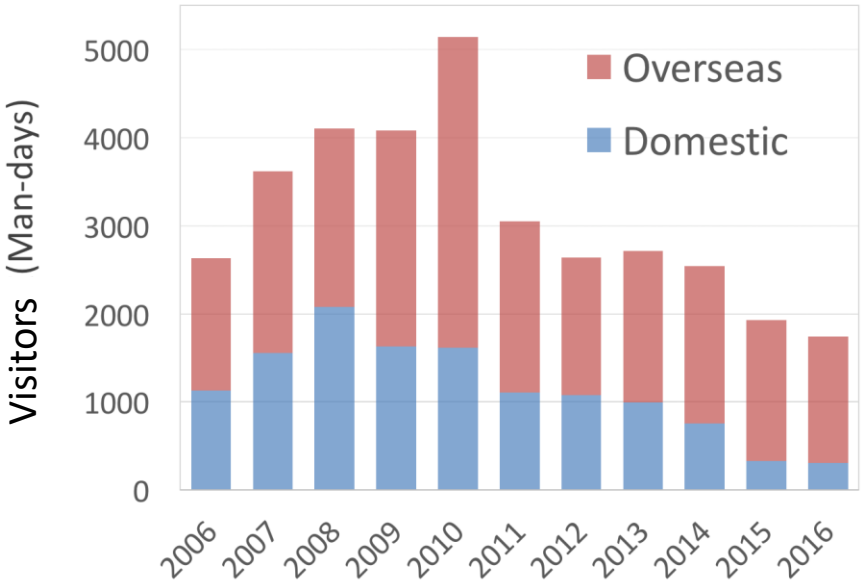
# ILC R&D at KEK

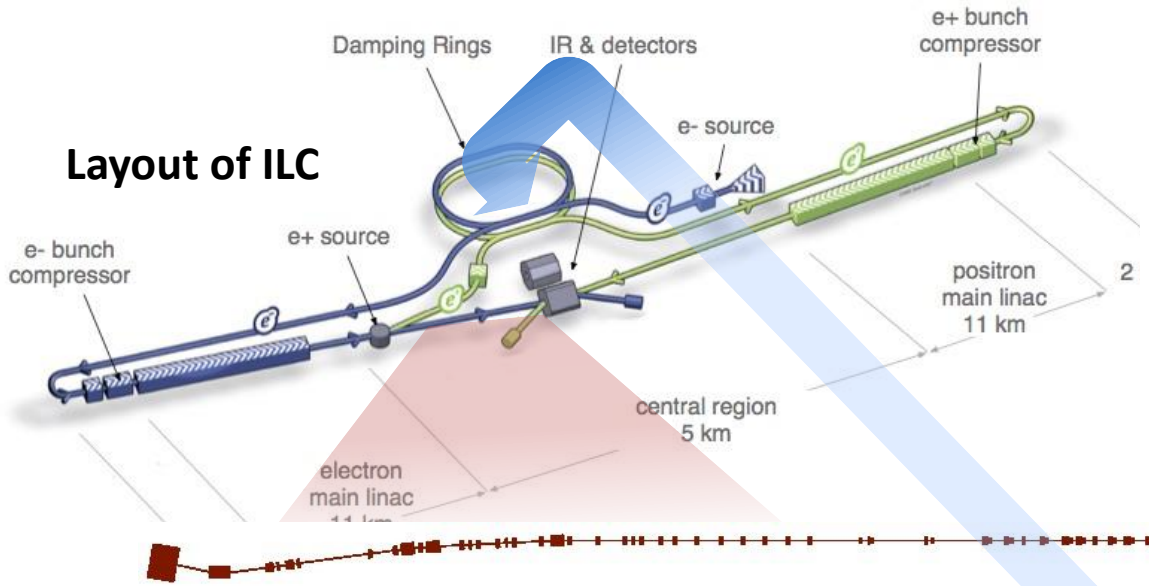


# ATF International Collaboration


- ATF international collaboration established in 2005.
- During the construction phase (~2010), many researchers joined for the installation of the components of in-kind contribution.
- Since 2011, the researchers visit for mainly the beam study.
- Many researchers are working for this collaboration.

# ATF/ATF2: Accelerator Test Facility




## Develop the nanometer beam technologies for ILC

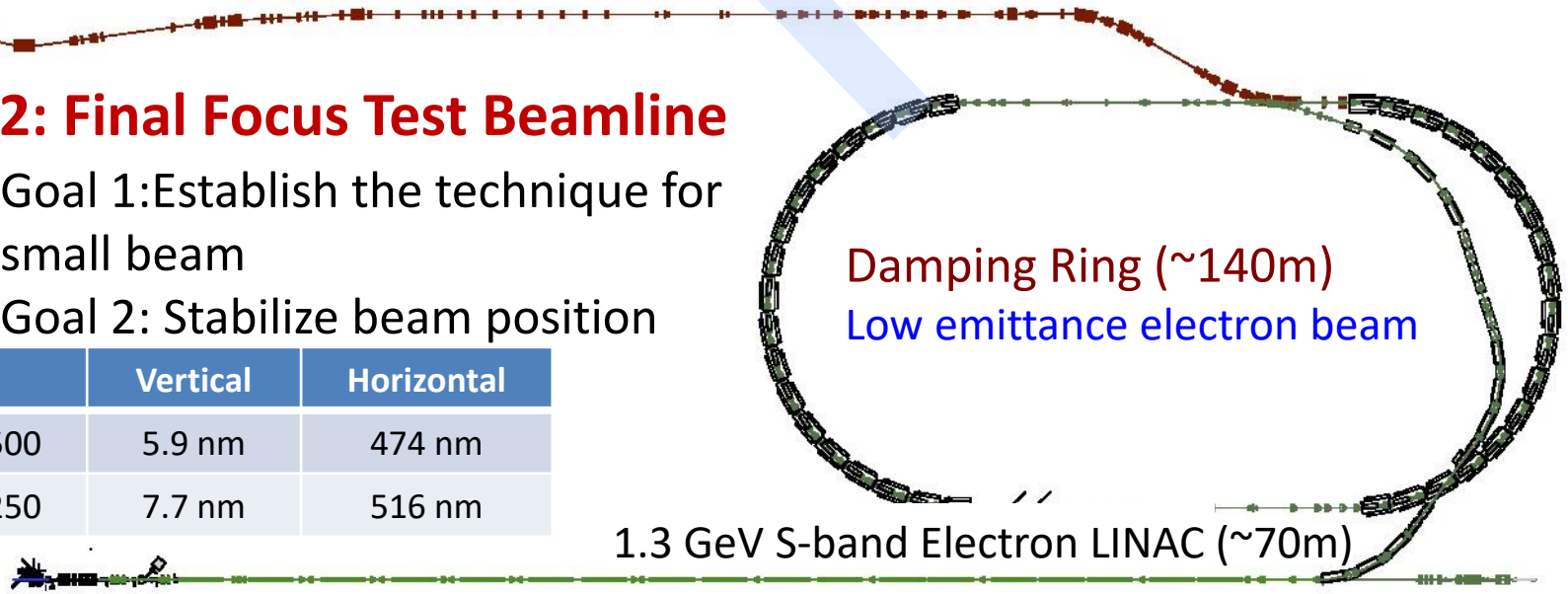
- Key of the luminosity maintenance
- 7.7 nm beam at IP (ILC250)

## ATF2: Final Focus Test Beamline

Goal 1:Establish the technique for small beam

Goal 2: Stabilize beam position

| | Vertical | Horizontal |
|---|---|---|
| ILC500 | 5.9 nm | 474 nm |
| ILC250 | 7.7 nm | 516 nm |



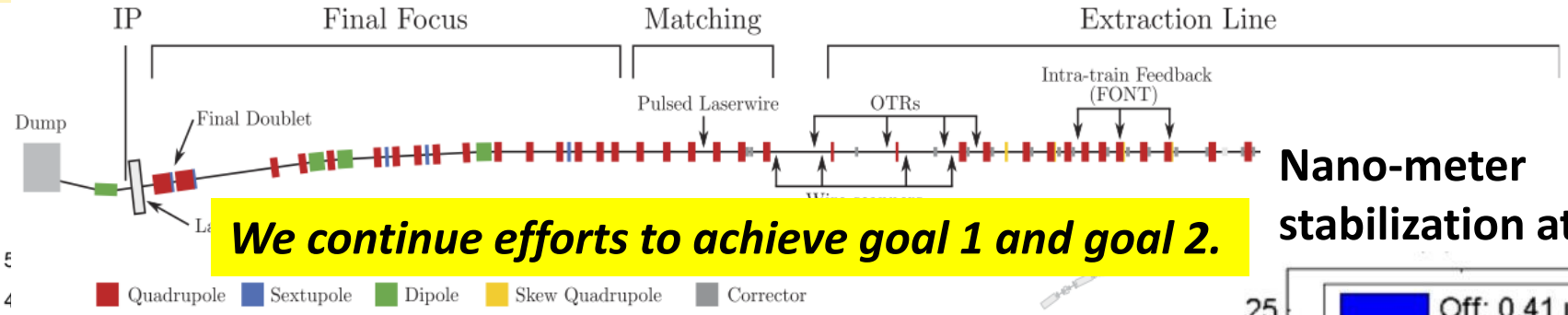
# Progress in FF Beam Size and Stability at ATF2

**Goal 1:** Establish the ILC final focus method with same optics and comparable beamline tolerances

- ATF2 Goal : 37 nm → 6nm @ILC500GeV
  7.7nm@ILC250GeV
  - Achieved **41 nm** (2016)

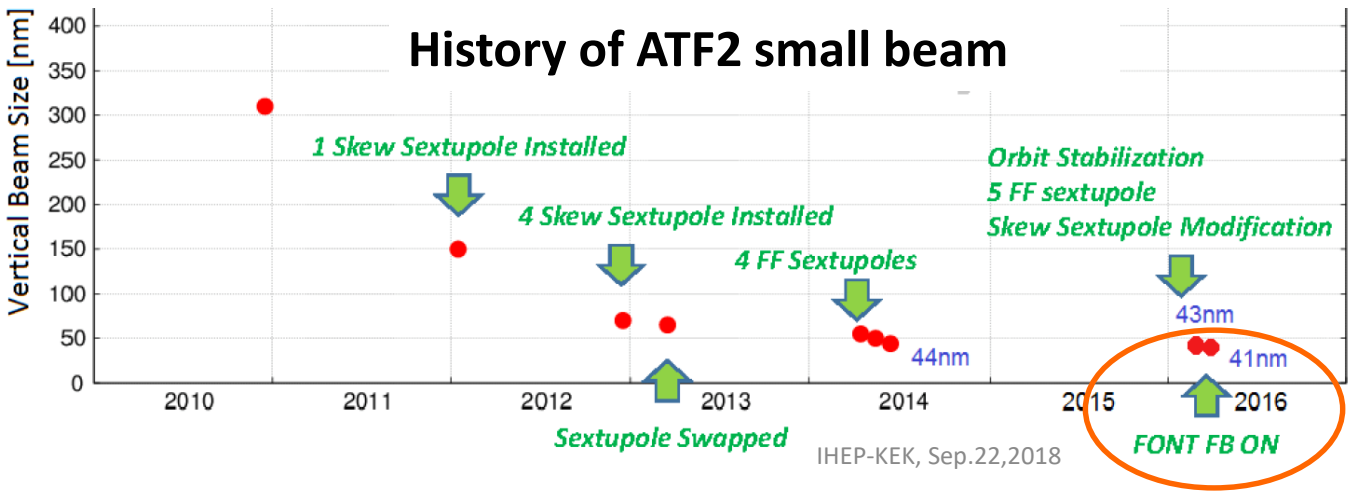
**Goal 2:** Develop a few nm position stabilization for the ILC collision

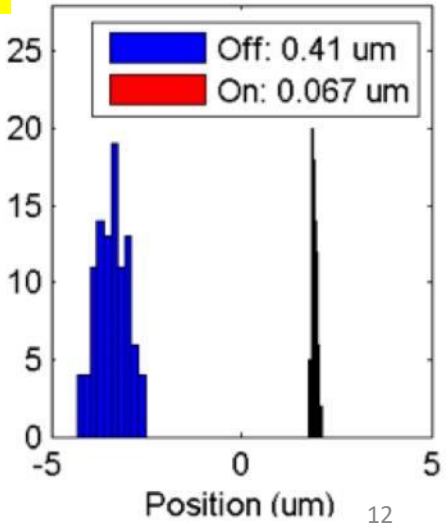
- **FB latency 133 nsec achieved** (target: < 300 nsec)
- **positon jitter at IP: 410 → 67 nm (2015)** (limited by the BPM resolution)




***We continue efforts to achieve goal 1 and goal 2.***

**Nano-meter stabilization at IP**



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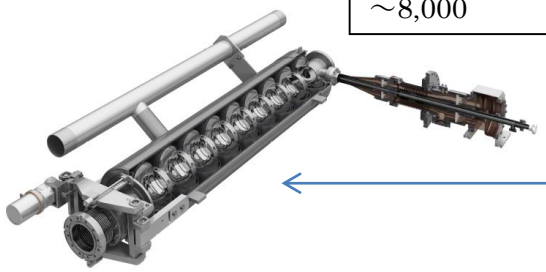
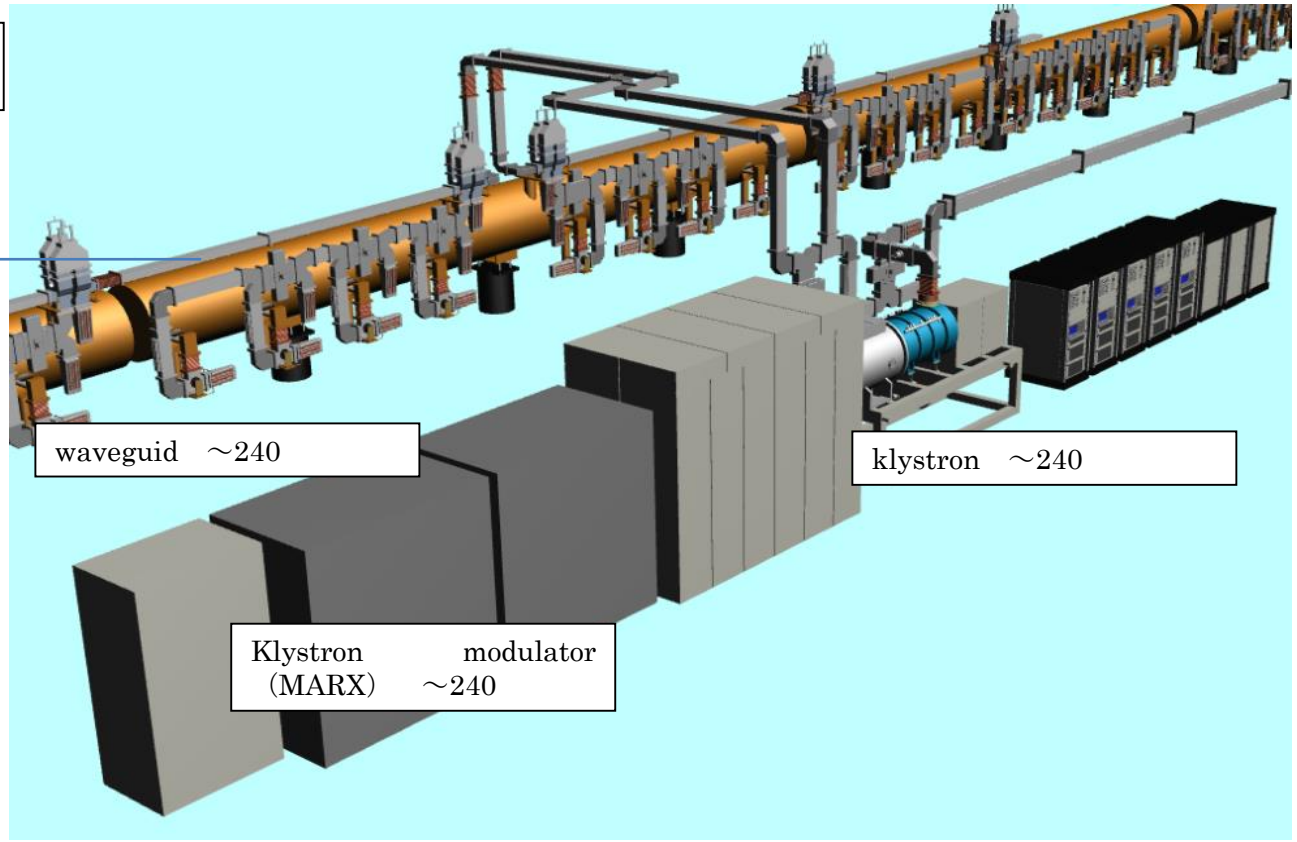
# SRF main linac at ILC250GeV



Input coupler
～8,000

cavity ～9,000




Number of cavities is 10% more than input coupler because of the yield of 90%.

# US-Japan Discussion Group on ILC

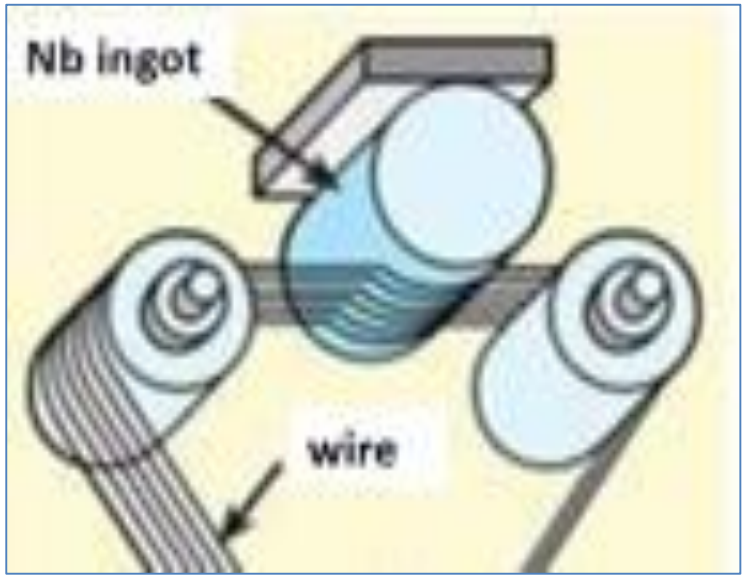
- First meeting on **May 25, 2016** at Washington D.C
  - Attended by Deputy Director-General, Research Promotion Bureau, MEXT, and Director, Office of Science, DOE.
  - Agreed on item of discussion
- Working level meeting on August 8, 2016 at ICHEP venue in Chicago
  - Attended by Director, Basic Research Promotion Div., MEXT, and Associate Director for HEP, DOE.
  - Heard from KEK and FNAL on the proposal of the joint R&D for cost reduction.
- Second meeting on **October 18**, 2016 by video
  - Attended by Deputy Director-General, Research Promotion Bureau, MEXT, and Director, Office of Science, DOE.
  - Agreed to begin the joint R&D from April 2017.
- Discussion group activity continues. The report on ILC Organization and Management is an input to this activity.

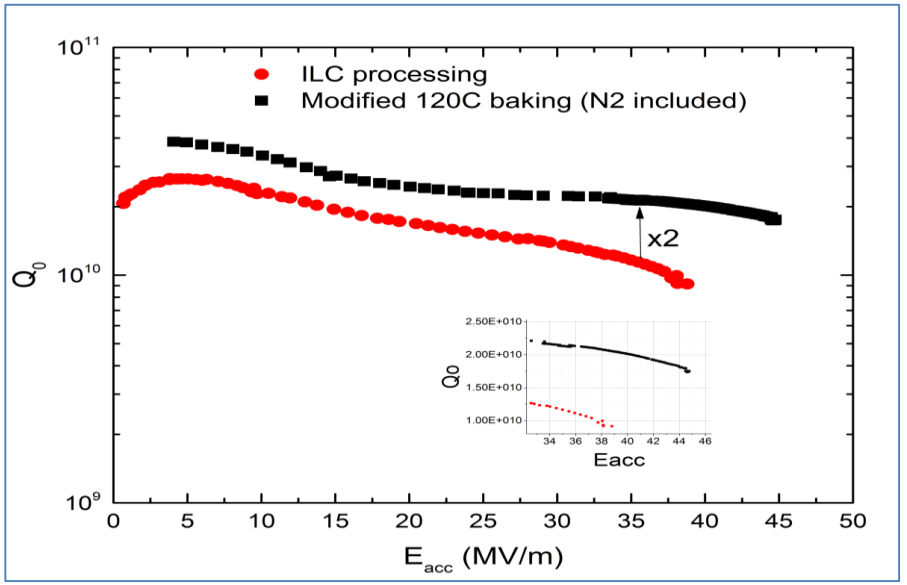
- R&D **program started** in **2017**

# ILC Cost-Reduction R&D in US-Japan Cooperation on SRF Technology, for ~3 years

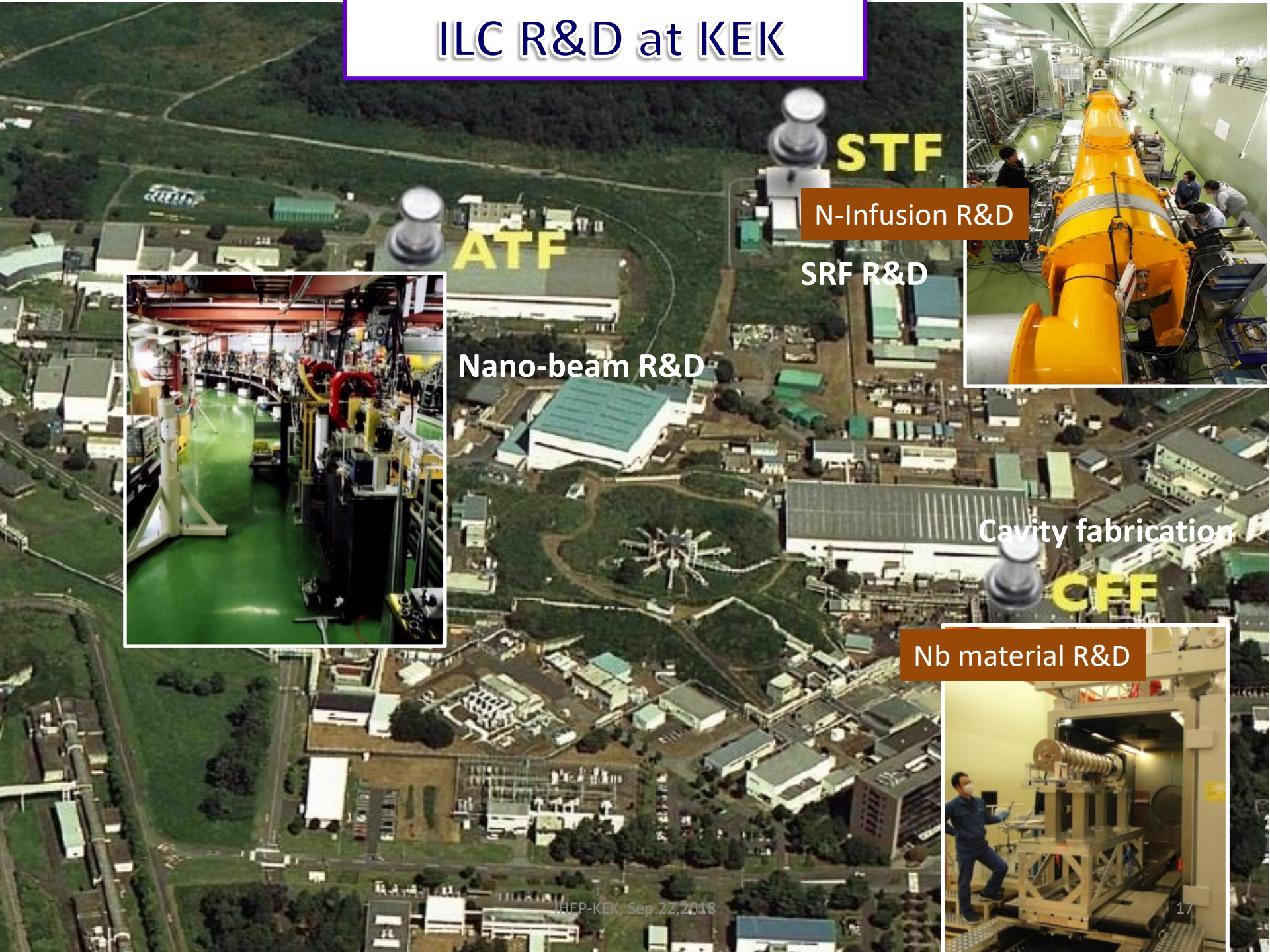
Based on recent advances in technologies;

- Nb materia/sheet preparation
  - w/ optimum RRR and clean surface
- SRF cavity fabrication for high-Q and high-G
  - w/ a new "N Infusion" recipe demonstrated by **Fermilab**



# ILC R&D at KEK

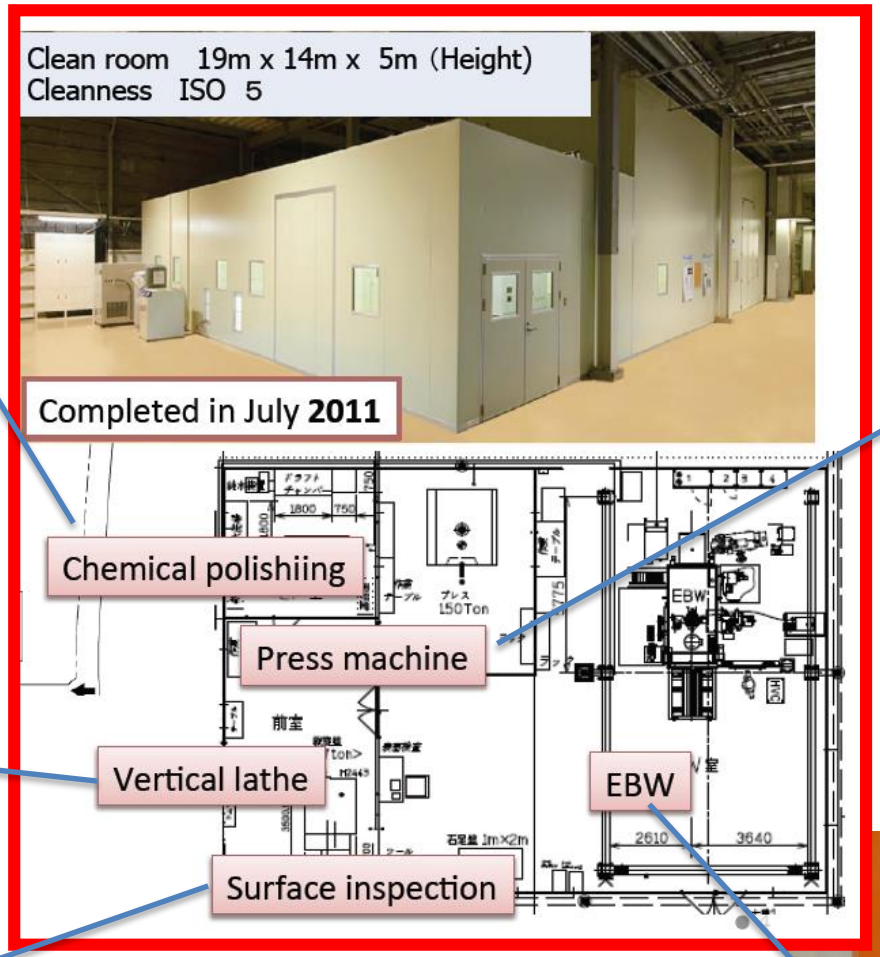

STF
ATF
N-Infusion R&D
SRF R&D
Nano-beam R&D
Cavity fabrication
CFF
Nb material R&D

# Main equipments in CFF

Chemical polishiing


CNC vertical lathe
(Moriseiki, Japan)

Microscope
(Surface inspection)



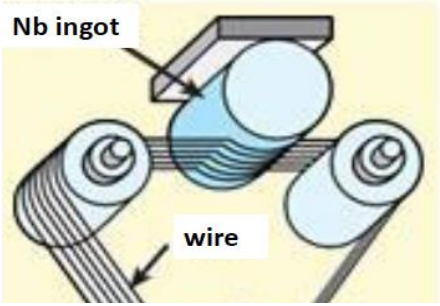


Servo press machine
(AMADA, Japan)
Max. applying force:1500 kN

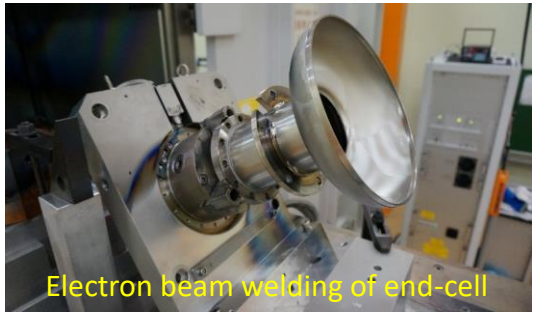

EB welding machine
（SST, Germany）
Max. beam voltage: 150 kV

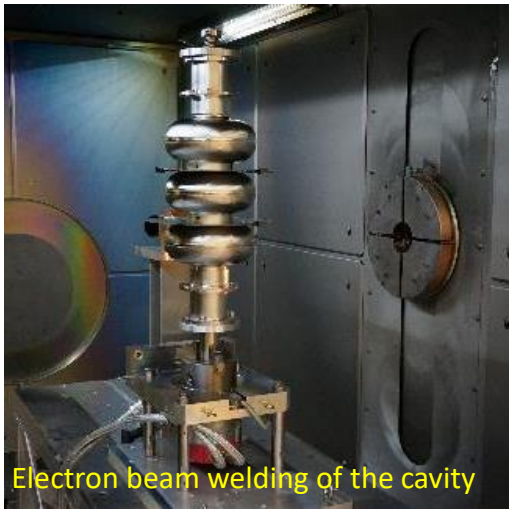
# Direct sliced Nb material performance

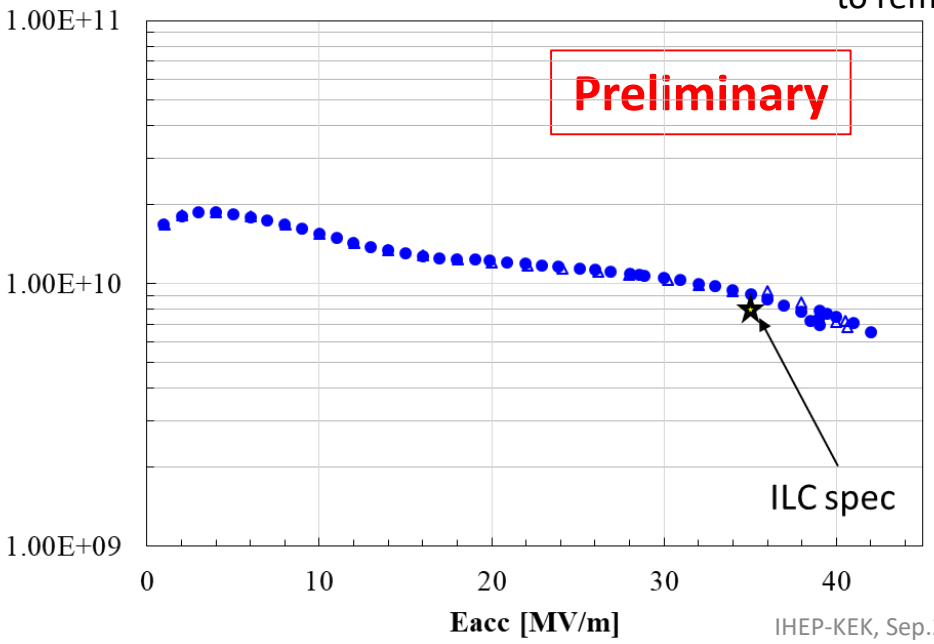
Made from large grain Nb disks;
medium RRR Nb with high Ta content




Annealed for
800℃ × 3hrs
to remove stresses.




- The 3-cell cavity achieved very high gradient (~42 MVm) and satisfies ILC spec.

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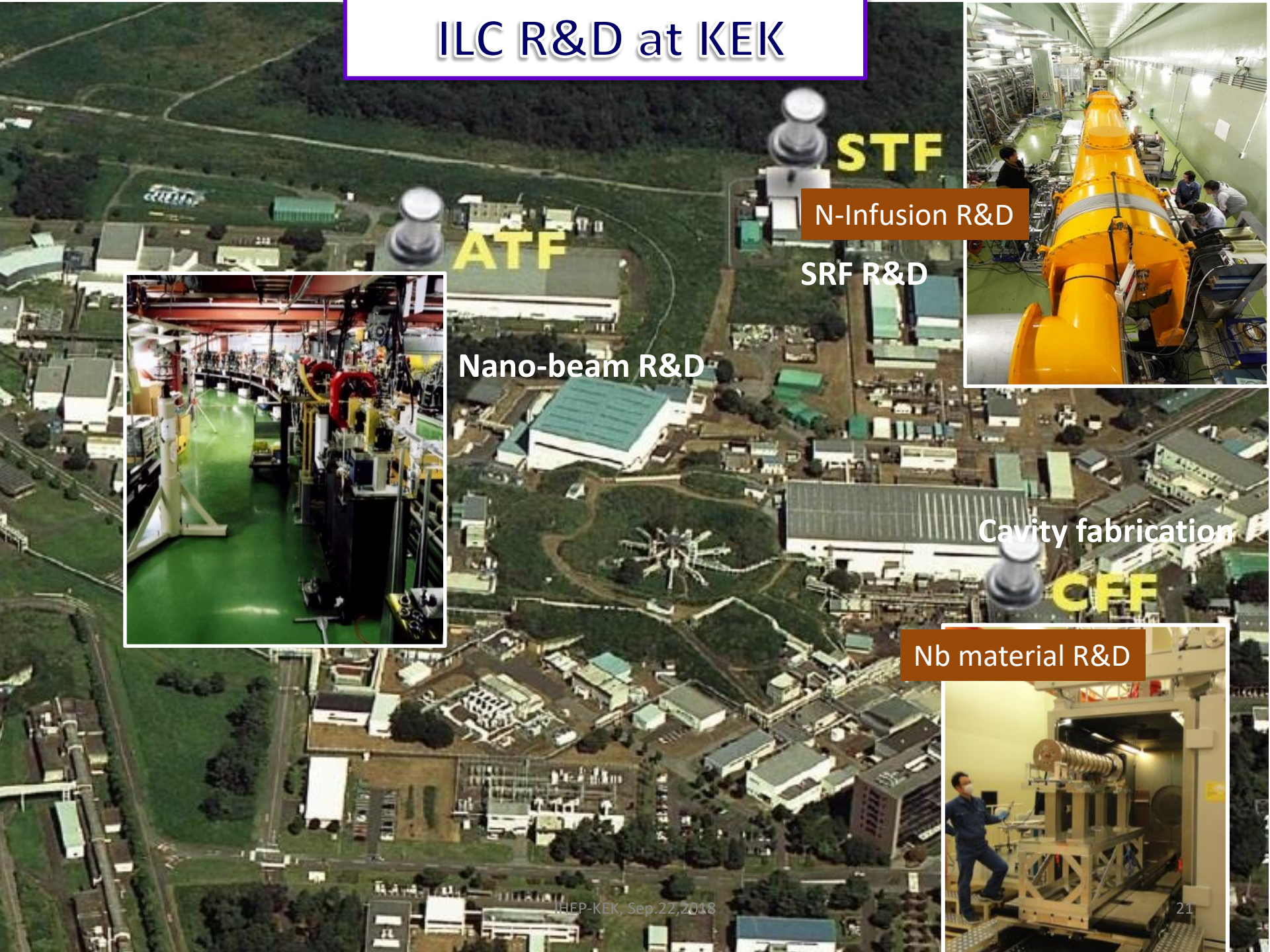
# ILC R&D at KEK


STF
ATF
N-Infusion R&D
SRF R&D
Nano-beam R&D
Cavity fabrication
CFF
Nb material R&D

# SRF equipments around STF

Electropolishing

Vacuum furnace

Vertical test

High pressure rinsing

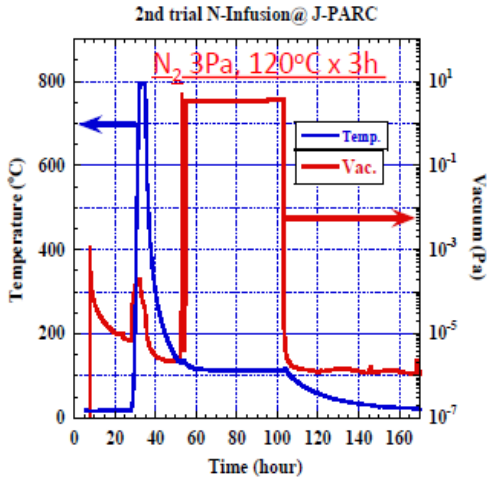
Clean room

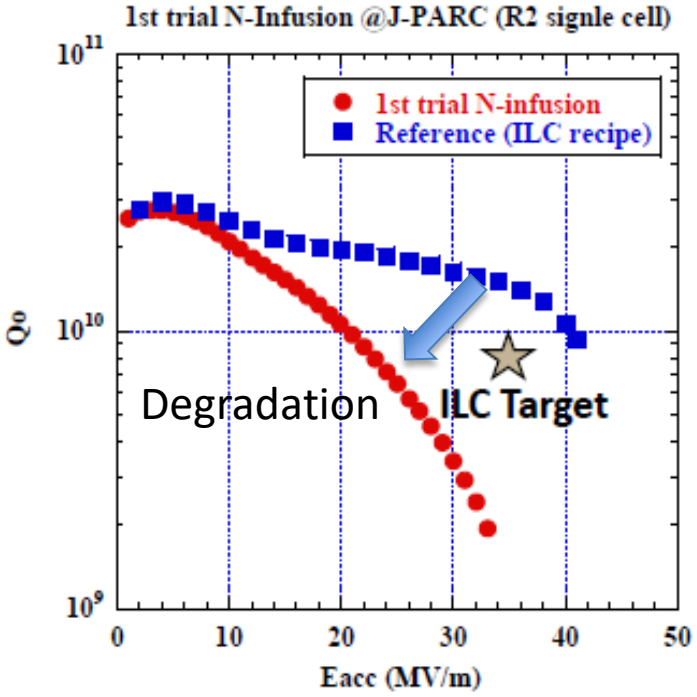
Horizontal test

STF-2

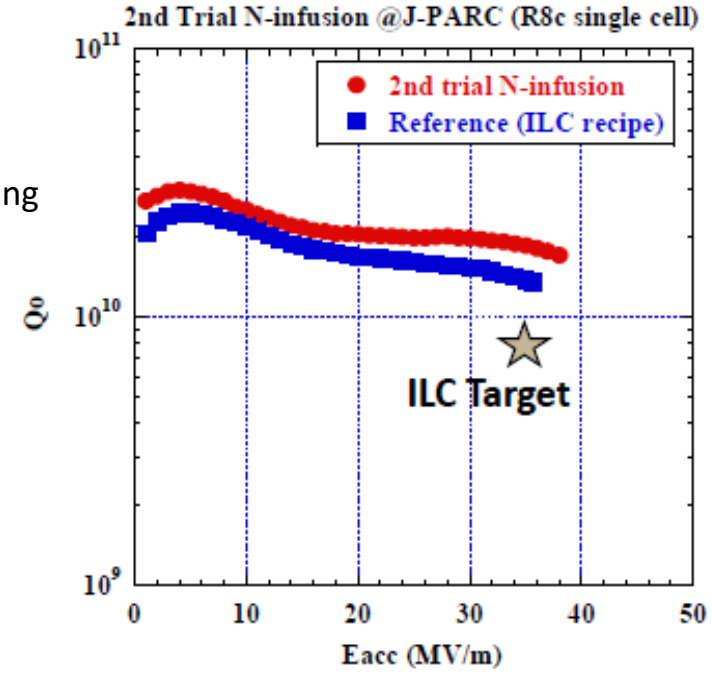
# Recent N-Infusion result at KEK

- First trial of N-infusion showed degradation occurred at >5MV/m.
- Degradation seems to come from background vacuum during 120deg. N-Infusion.
- Background vacuum during N-Infusion was improved from 1.7e-2Pa to 1e-5Pa using larger turbo-molecular pump with reduced rotation speed.
- Second trial of N-Infusion was done with improved background vacuum during N-Infusion (120 deg.)
- It showed successful N-Infusion result (Q value +35% gradient +5%).




After the vacuum pumping system improvement



# US-Japan cost reduction R&D

***Evaluate the cavity performance from vertical test to horizontal test***

Cavity fabrication

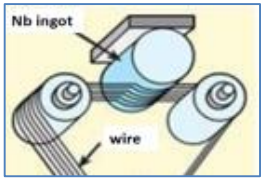
Heat treatment

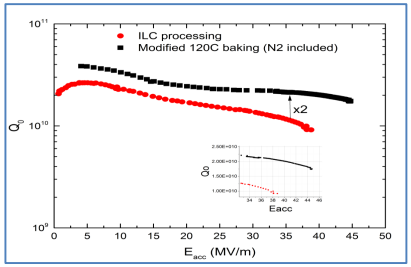
Vertical test

***N-Infusion***

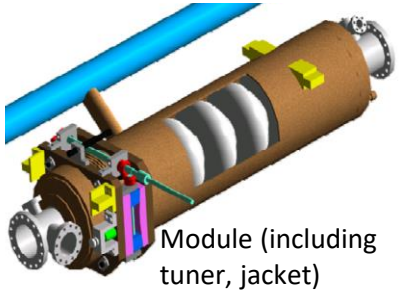
| | |
|---|---|
| | Standard Fabrication/Process |
| Fabrication | Nb-sheet purchasing |
| | Component Fabrication |
| | Cavity assembly with EBW |
| Surface Process | EP-1 (~150um) |
| | Ultrasonic degreasing with detergent, or ethanol rinse |
| | High-pressure pure-water rinsing |
| | Hydrogen degassing at ~~> 600 C~~ → 800 C |
| | Field flatness tuning |
| | ~~EP-2 (~20um)~~ |
| | ~~Ultrasonic degreasing or ethanol (or EP 5 um with fresh acid)~~ |
| | High-pressure pure-water rinsing |
| | Antenna Assembly |
| | Baking at 120 C (+ N2 infusion) |
| Cold Test (vertical test) | Performance Test with temperature and mode measurement |
| Cryomodule | Installation to the cryomodule |

***New Nb material/process***




Degradation-free environment



Module (including tuner, jacket)


Horizontal test

Module test at stF-2

# Recent ILC R&D status

*Shin MICHIZONO*
*KEK/Linear Collider Collaboration (LCC)*

- *250GeV ILC*
- *Nano-beam R&D*
- *Cost reduction SRF R&Ds*
  - *Directly sliced Nb material*
  - *N-infusion*
- *SRF accelerators*
- *Fukuoka Statement/ILC symposium*

# Fukuoka Statement

LINEAR COLLIDER COLLABORATION

**Statement on "Towards the realization of the International Linear Collider, an update"**

https://www.kek.jp/ja/newsroom/attic/20180531_ilc_fukuokastatement.pdf

31 May 2018, Fukuoka

Scientists who gathered for the Linear Collider Workshop in Tokyo in 2015 issued a statement confirming their strong support for the scientific justification for a prompt realization of the International Linear Collider (ILC). The Linear Collider Collaboration (LCC) and the worldwide participants at the 2018 Asian Linear Collider Workshop (ALCW2018) in Fukuoka, Japan, reconfirm the scientific importance of the ILC. We are closer to the realization of the project, but it is now in a critical phase.

(1) Results to date from the CERN Large Hadron Collider indicate that we are at a crossroads in our quest to uncover the origin and history of the Universe. We now know that precision measurements, in particular of the properties of the Higgs boson, are an essential next step to advance our understanding. Precise measurements in electron-positron interactions at a center of mass energy of 250 GeV at the ILC will deliver a leap in our scientific knowledge and, together with future results from the LHC and SuperKEKB, will propel us toward the ultimate theory of particle physics and a deep understanding of the Universe itself.

(2) We have been preparing for the ILC for many years, in collaboration with industries and in discussion with governments worldwide. The ILC is now the most mature and realizable electron-positron collider project, and offers the energy expandability of a linear collider. The successful operation of the European XFEL in Hamburg and recent advances in the superconducting R&D in Fermilab near Chicago and other laboratories, together with a cost reduction by changing the initial center of mass energy to 250 GeV, increases the ILC technical and financial feasibility whilst maintaining the physics potential of the machine at this energy. The superconducting technology being developed for the ILC has a great impact on industrial and medical applications of accelerators. We deeply appreciate the evaluation process by the Japanese government for the proposal based on the new ILC design.

(3) The ILC can only be realized as an international project, and a nation who wishes to host the project should lead the international negotiations. A positive message from the Japanese government expressing readiness to initiate these discussions this year is critically important because work on the update of the European Strategy for Particle Physics, including collaboration in the ILC construction, will start early next year. This update will have a large impact outside Europe on the future of high energy physics projects worldwide. While we will strongly present the scientific case for the ILC in these discussions, it is essential to hear a positive message from the Japanese government in a timely manner.

Lyn Evans
LCC Director
For scientists from LCC and ALCW2018

LINEARCOLLIDER.ORG


Matured SRF accelerator
Recent R&Ds

# An International Symposium

http://www-conf.kek.jp/SRF_for_ILC/index.html

High Energy Accelerator Research Organization (KEK),
Linear Collider Collaboration (LCC) and
International Center for Elementary Particle Physics (ICEPP)
cordially invite you to the symposium on:

## The Superconducting RF technology for the International Linear Collider

**Monday, June 25th, 2018, at 10:00**
**Fukutake Learning Theater, The University of Tokyo**

# Symposium program

● General overview

| | | |
|---|---|---|
| 10:00 | **Opening address** | Masanori YAMAUCHI (KEK, Japan) |
| 10:10 | **Physics at the ILC and international collaboration** | Sachio KOMAMIYA (Waseda University, Japan) |
| 10:35 | **Accelerator technologies of ILC and their applications** | Shinichiro MICHIZONO (KEK, Japan) |
| 11:00 | **A global collaboration for the ILC** | Lyn EVANS (Linear Collider Collaboration, UK) |
| 11:10 | **US SRF R&D status** | Sergey BELOMESTNYKH (Fermilab, U.S.A.) |
| 11:35 | **European XFEL experiences demonstrating the SRF technology for the ILC** | Hans WEISE (DESY, Germany) |
| 12:00 | **Advances in SRF technology and future prospects in China** | Jie GAO (IHEP, China) |
| 12:25 | *Lunch/Media briefing* | |





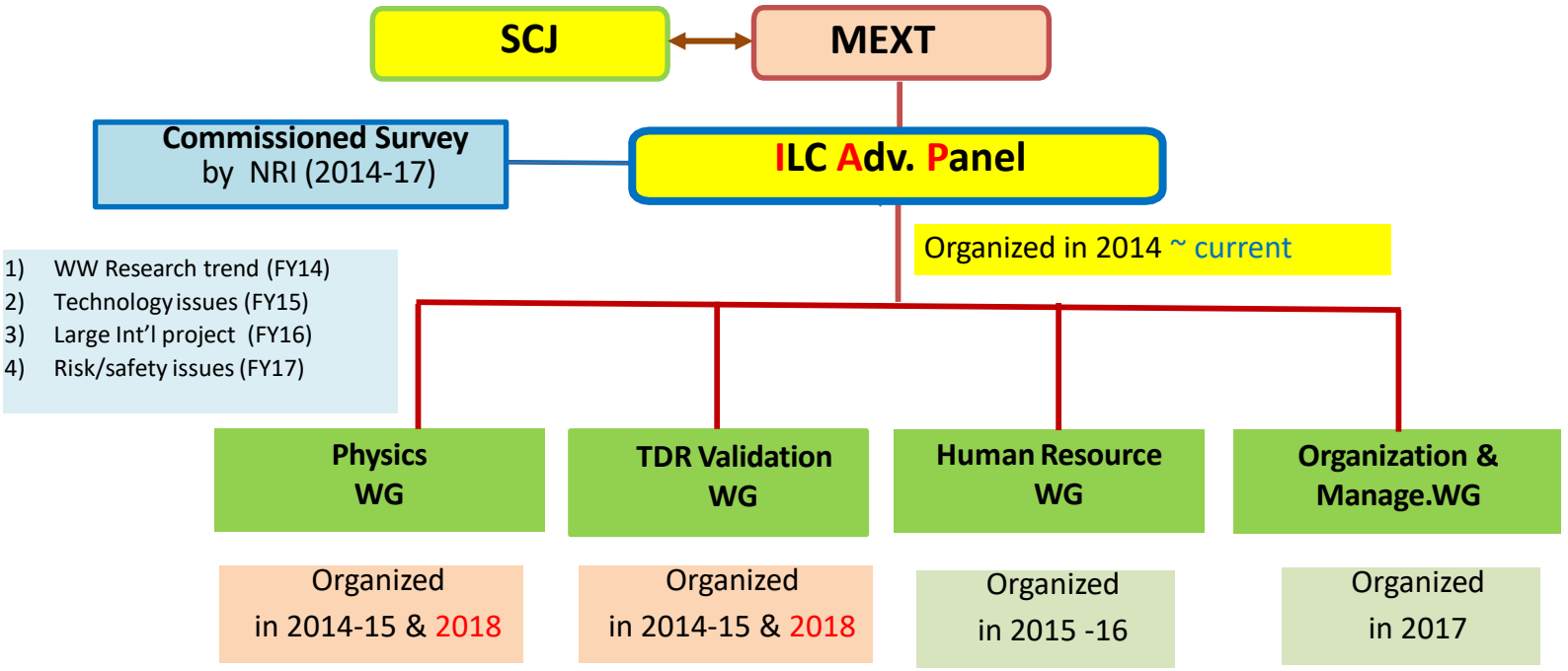


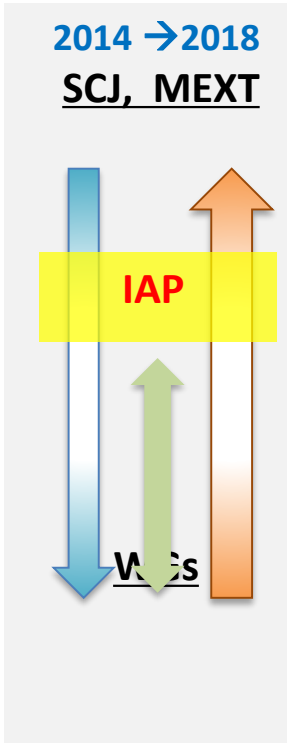

● Technical discussion

Recent status and R&Ds were reported by the world-wide researchers.

| | | |
|---|---|---|
| 13:30 | **N-Infusion, new SRF technology with higher performance** | Anna GRASSELLINO (Fermilab, U.S.A.) |
| 13:55 | **SRF technology R&D at JLAB, and the future prospects** | Ari PALCZEWSKI (Jefferson Lab, U.S.A.) |
| 14:20 | **ILC cost reduction R&Ds at KEK** | Kensei UMEMORI (KEK, Japan) |
| 14:45 | **Collaboration for high efficiency SRF system at reduced cost** | Ganapati MYNENI (ISOHIM, U.S.A.) |
| 14:55 | *Break* | |
| 15:20 | **Industrial application of SRF accelerator** | Hiroshi KAWATA (KEK, Japan) |
| 15:45 | **Application of SRF Linac for IFMIF Prototype Accelrrator** | Atsushi Kasugai (QST/Rokkasho, Japan) |
| 16:10 | **The history of industrialization in SRF technology and prospects for future** | Katsuya SENNYU (Mitsubishi Heavy Industry Machinery Systems, Japan) |
| 16:35 | **Adjourn** | |

# ILC Study Coordination by MEXT




- Physics WG, and TDR Validation WG re-organized to evaluate ILC-250GeV.

ILC Advisory panel report is now available from MEXT web site.
http://www.mext.go.jp/component/b_menu/shingi/toushin/__icsFiles/afieldfile/2018/09/20/1409220_2_1.pdf

***Thank you for your attention***